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FINAL DELIVERABLE

Title	Don Williams Recreation Area Amphitheater Design
Completed By	Alexander Kluver, Andrew Quested, Nathan Kemmer
Date Completed	December 2018
UI Department	Civil and Environmental Engineering
Course Name	CEE:4850:0001 Senior Design
Instructor	Paul Hanley
Community Partners	Boone County Conservation

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> [Student names], led by [Professor's name]. [Year]. [Title of report]. Research report produced through the Office of Outreach and Engagement at the University of Iowa.

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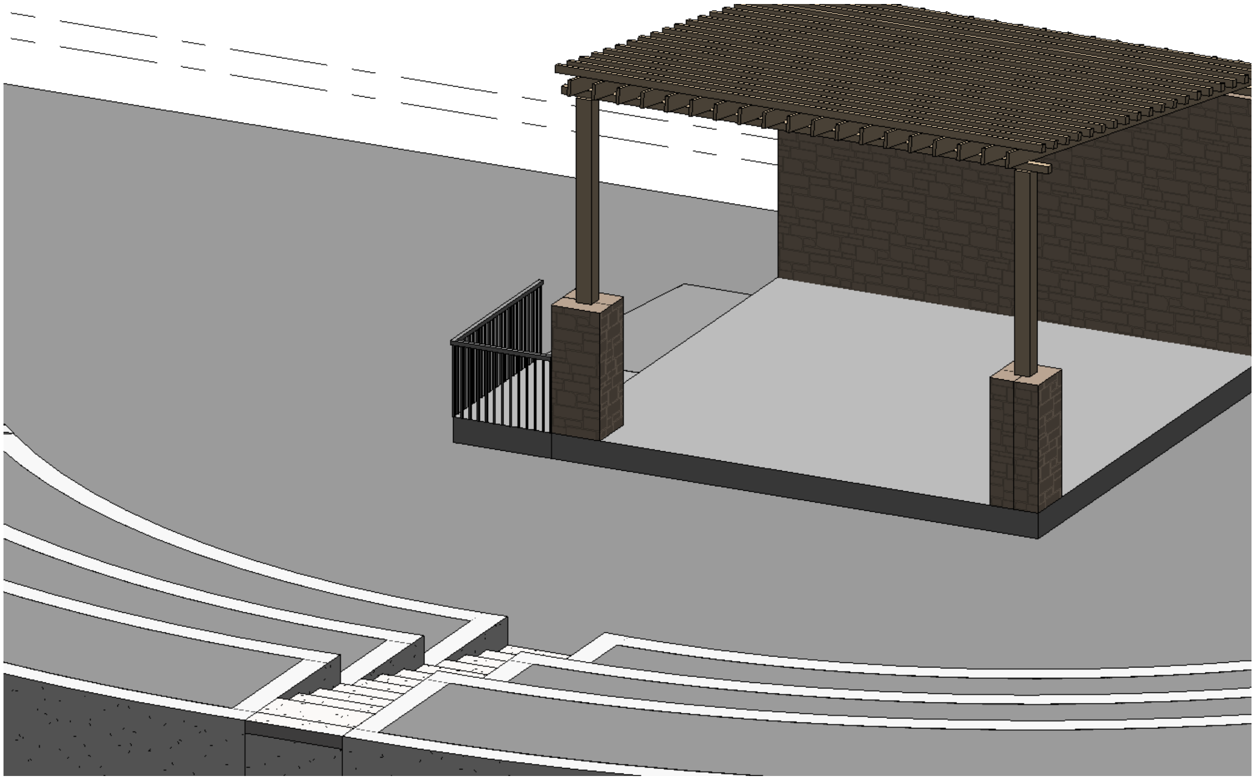
Natural Amphitheater in Campground C in the Don Williams Recreation Area

610 H Ave, Ogden IA 50212



ANA Engineers

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Section I - Executive Summary

We are a team of senior Civil Engineering students who will be graduating from the University of Iowa in December, 2018. We have decided to call ourselves ANA Engineers. For this project, we have designed a natural amphitheater for the Don Williams Recreational Area in Boone County, Iowa. Individually, the ANA Engineers have experience from internships and have taken courses to give us knowledge in structural engineering, transportation, and hydrology, which have prepared us to design this amphitheater. The tasks included with this design process were to design the stage, seating, parking, and site grading.

The seating is designed to be a 20’ by 20’ concrete slab with a structure built up from the slab. The front side of the stage has two columns standing on either side. The columns are built out of a combination of concrete and timbers. The concrete columns are 1’ by 1’ with a height of 2’4”. They are wrapped by limestone veneers to add a natural stone look. The timbers are 8” by 8” and extend from the center of the concrete columns all the way to the roof. The back side of the stage is designed to be built up as a masonry load bearing wall. The wall extends from the slab to the roof of the structure. The wall is also wrapped with the limestone veneers to add a natural design aspect. The roof of the structure is designed as a pergola style roof. It consists of (19) 2” by 8” by 22’ sawn treated lumber that are angled at roughly 9 degrees and spaced 1’ apart from each other. The 2” by 8” lumber are connected to (2) 4” by 4” by 20’ beams which are attached to the front timber columns and the rear concrete masonry unit wall. On top of the 2” by 8” lumber are (20) 4” by 4” by 20’ sawn treated lumber which are spaced 1’ apart. The stage also includes a concrete ramp on one side of the slab to allow for ADA accessibility.

The seating is designed to accommodate an audience of around 115 persons. It is comprised of three tiers of seating created out of a combination of concrete retaining walls and natural grass in between the walls. The concrete walls are designed as arcs and are 1’ thick. The front wall protrudes 1.5’ from the ground and extends 3.5’ below the surface to go below the frost line. The second wall sits 6’ behind the front wall. The space in between the two arcs are filled with grass to provide a natural look. The second tier sits 1.5’ taller than the first tier, and the third tier sits 1.5’ taller than the second tier. The three tiers are split in half by a staircase which is 4’ wide. The staircase is comprised of 12 steps that are each 4.5” in height and 1’ 9” in length. In front of the seating area is a concrete slab which serves as a location for accessible seating.

The parking is designed to meet specifications from the Americans with Disabilities Act. With the seating designed to hold between 100 and 150 people, two ADA accessible parking spaces need to be provided. The parking spaces were added to the existing road going through the park at a location just to the south of the stage. Each parking space is 11’ wide and 18’ long with an 8’ wide access isle between the two spots. An 18’ concrete pad was added to each side of the parking spots in order to assist users trying to park in these spots.

The cost estimates for this project were determined using RS Means Cost Estimation Handbook. The cost for the stage was estimated to be a total of about $15,500, the cost for the seating design was estimated to be around $22,000, and the cost of the parking was estimated to be about $5,500. The cost estimate for cut and fill of the site is about $44,000. This gives a total cost for the project to be about $87,000. This price includes overhead and profit. For finer details of the cost estimation, refer to Secton VII.

The members of the ANA Engineers used programs such as AutoCAD, Civil 3D, Revit, and ArcGIS to design the various aspects of this project. We have been pleased to design this Natural Amphitheater for the Don Williams Recreational Area and believe that it should meet expectations.

Section II - Organization Qualifications and Experience

1. Name of Organization:

   ANA Engineers

2. Organization Location and Contact Information:
   a. Nathan Kemmer
   b. Phone # - (319) 210-1205
   c. nathan-kemmer@uiowa.edu

3. Organization and Design Team Description:

   We are a team of civil engineering students who are studying at the University of Iowa in our capstone design class. Nathan Kemmer, project manager, has focused his studies on Structures, Materials, and Mechanics. Nathan focused on the stage design and structural aspects of the project. Andrew Quested has focused his studies on Civil Engineering Practice while also earning a math minor. Andrew focused his time on the seating design and drainage issues for the project. Lastly, Alexander Kluver has focused his studies on transportation. Alexander focused on the accessible parking spaces and also helped Andrew with drainage issues.

Section III - Design Services

1. Project Scope:

   The natural amphitheater was designed and set in campground C of the Don Williams Recreation Area. The design incorporates the sloping topography of the location and uses native Iowan materials, such as natural stones and oak wood. The amphitheater stage is open with little to zero shade to provide natural lighting to the persons performing on stage. It will be built off the ground and showcases an overhang that invites persons to come watch. It includes a backdrop built as a concrete wall and wrapped with natural stones. The overhang uses Iowa's native materials and blends in with the trees in the background. The seating is placed within the earth and allows for lawn to be grown in-between the tiers of seats. The seating uses concrete as a retaining wall for the earth and provides natural seating for visitors. A concrete slab was included in front of the seating to serve as a platform for accessible seating. Accessible parking spaces were also added in our project site in order to meet the Americans with Disabilities Act specifications.

2. Work Plan:

Figure 1. Work Plan Gantt Chart

Section IV - Constraints, Challenges, and Impacts

1. Constraints:

   There were several constraints within our project to consider: building location, requirements given by the client, and time. The building location, which is sloped prairie land, gave an issue of where to place the structure and its seating. The requirements given by the client were to ensure the design incorporated natural Iowan materials such as limestone and native Iowan timber. Another requirement given by our client was to ensure that the amphitheater was large enough to entertain a minimum of 100 people. Lastly, time was a constraint due to our group of student engineers graduating December 16th and the term extending only to December 7th. After December 7th, our organization will no longer be spending time on this project.

2. Challenges:

   The largest challenge this project was faced with was drainage. The desired location of the project will be on a sloped surface, naturally when the area receives a storm, the accumulated water will flow through the projected building site. Along with the rainwater flowing through the site, the project faced a challenge of not allowing water to flow over the seating or pooling onto the stage. The stage seating design incorporates a grassy area in-between seats, this brings up the issue of water pooling in-between the seats. Our client asked to have an Americans with Disabilities Act parking area. This left a challenge of ensuring rainwater also did not pool within the parking spots.

3. Societal Impact within the Community and/or State of Iowa:

   It is reasonable to assume that this project will increase noise levels within the Don Williams Recreation Area; however, the noise is controllable by enforcing a quiet hours ordinance. The project will positively affect the daily lives of campers and visitors to the recreation area, since it will provide a new venue for multiple forms of entertainment. Major characteristics of the social environment, such as property rights and population characteristics, will not be affected because the project location is on an unused section of the recreation area.

Section V - Alternative Solutions That Were Considered

Amphitheater Stage Alternatives

An important alternative design was the roofing of the projects stage. The project was requested by our client to replicate a pergola style roof. The alternative to the pergola roof would be to have a completely covered roof. The pros to this design is to relieve the stage from natural elements from damaging the stage and sheltering the stage performers from these elements. Along with the roof, the stage has a few other alternative options. The load bearing wall is designed as a concrete masonry unit wall. This reduces cost and increases stability. The other options explored was to use a reinforced concrete wall, limestone block, or have the wall open supported by timber. The reinforced concrete wall pros would be increased bearing capacity as well as resistance to forces. However, the major con to this was the cost of building a reinforced concrete wall, as the construction cost would be much greater. The limestone block alternative design would have been very aesthetically pleasing, however the con is a major increase in cost versus the masonry and reinforced concrete wall. Having timber columns in the rear instead of a wall would have increased the depth of the stage, and brought down cost. However, the downside to removing the wall would have required a much higher capacity for loading on the roof. Another downside is the impact of the acoustics. Without a back wall, it is more difficult to project sound forward towards the audience.

Stage Seating Alternatives

One alternative design for the seating design was to use large limestone blocks instead of reinforced concrete. The pros to this design is that limestone is a natural material in Iowa and would have added a very attractive aspect into the seating. However, one of the downfalls of the limestone slabs is that the cost would increase. Another con for this design is that with the seats being in an arc shape rather than in straight lines, it would have been difficult to construct a curved seating wall out of the large limestone slabs that looks proper. Concrete is easier to form to a desired shape which is a major deciding factor as to why the limestone blocks were not used. Another alternative was to have bench seating going down the hill rather than building seats into the land. This would have resulted in a less expensive design because little earthwork would need to be done, it could have added more seats in order to hold larger crowds, and they would be easier to maintain. The problem with this design is that it would result in a lack of creativity and appeal. Since this was not in the scope of the work and our client wanted a more natural design, we decided to abandon this design alternative.

Section VI - Final Design Details

Our team designed an amphitheater which included the stage, seating, and accessible parking. In this section we will present the stage and its components, the seating and its components, the site drainage and hydraulic analysis, and finally the parking design.

Concrete Foundation

The foundations for the amphitheater structure were designed to have two separate dimensions. The front side of the amphitheater will have two columns protruding upward on both sides to support the roof. The columns consist of a concrete sections this is 1’ by 1’ with a height of 2’4” with an 8” by 8” timber coming out the top of the concrete. The timber will sit inside the concrete at a depth of 1’ and extend to the roof. The concrete used should have a compressive strength of 4000 psi and incorporate grade 60 size #4 rebar to increase the tensile strength of the foundation. The footing below the column should 3’ by 3’ and have a depth of 8”. It will use a concrete mixture with a compressive strength of 3000 psi and will be reinforced by the rebar from the column. The rear foundation will use the same column setup as the front but will have a wider and longer dimension for the footing. The footing has been designed to be 20’ by 5’ with an 8” depth. It should us the same 3000 psi concrete mixture and be reinforced by the rebar from the column. The design standards for the columns and footings were the International Building Code 2015 Chapter 18 and ASCE 7-16 Chapter 6. The foundations were considered nominal for bearing capacity, sliding resistance, and uplift forces. A further in-depth overview of the foundation calculations is found in Appendix A under the “Foundation Calculation for Columns” on page 24-26 and under “Foundation Calculations for Wall side” on page 20-23. The drawings of the foundations can be seen on Sheet B.2 and Sheet B.4.

Concrete Flooring

The flooring design is a concrete slab that is 20’ by 20’ and 6” in depth. It uses a concrete mixture with a strength of 3500 psi. The flooring was designed to withstand pressures from live loading and compressive stress from the rear wall and front columns. To withstand thermal cracking and expansion, the slab has been designed to incorporate grade 60 #4 rebar in both directions to increase tensile strength. The amount of rebar and spacing calculations can be found in Appendix A under the “Concrete Floor Reinforcement/Thermal Cracking” section on page 28.

The design standard used was the International Building Code 2015 Chapter 19. The drawings of the floor can be seen on Sheet B.2.

Masonry Load Bearing Wall

The rear load bearing wall design consists of 225 8” by 8” by 16” concrete masonry unit (CMU) blocks with two cells in each block. The 225 blocks will comprise a 20’ by 11’ by 8” CMU wall which will be reinforced by vertical #4 rebar in every other cell. Along with the vertical reinforcement the CMU block cells will be filled with 200 total square-feet of grout. The compressive strength of the wall given by the weight promotes strong resistance to horizontal wind pressure and prevents the attached roof to resist vertical uplift. Once constructed the wall will be given weathering resistance, mortar, and will have limestone veneers wrapped around the wall to give a native Iowan look. When finished the wall will be approximately 12” thick. Calculations for nominal strength can be found in Appendix A under “Masonry Wall Calculations” on page 27. The drawings of the load bearing wall are found on Sheet B.2, B.3, and B.5. Design standards used for the CMU wall were International Building Code 2015 Chapter 21 and ASCE 5-11 Building Code Requirements and Specification for Masonry Structures.

Timber Column and Roof

The amphitheater designed incorporates two 8” by 8” by 15’ treated heavy structural lumber columns. The two columns were designed to each withstand load combination 3 on a tributary area of 100 square-feet. The columns are to be inserted into the concrete column 1’ below the concrete floor. This will reinforce the timber and reinforce allowing for a greater resistance to horizontal and vertical wind pressures. The compressive strength of the timber columns were found to be nominal given the density of the wood and maximum loading of the roof given by load combination 3. The roof consists of (19) 2” by 8” by 22’ sawn treated lumber that are angled at roughly 9 degrees and spaced 1’ apart from each other. The 2” by 8” lumber are connected to two 4” by 4” by 20’ beams which are attached to the front timber columns and the rear CMU wall. On top of the 2” by 8” lumber are (20) 4” by 4” by 20’ sawn treated lumber which are spaced 1’ apart. Calculations on the lumber can be found in Appendix A under “Dead

Load of Roof Calculation” on page 18. Details of the timber columns and roofing can be found on Sheet B.2 and B.3.

Concrete Walls and Stairs

The seating design consists of four large concrete retaining walls in arc shapes that are each a foot thick. In between the arcs will be grass to provide a natural look. The front three arcs are a total of 5’ in height, while the back arc is only 3’ 6” in height. This is because the front three arcs are designed to be the location for spectators to sit. The front arc protrudes 1’ 6” from the ground, the second arc is 1’ 6” higher than the first, and the third is 1’ 6” higher than the second. The back arc sits at the same height as the third arc. All of the walls extend 3’ 6” below the surface to go below the frost line. The concrete used should be class C concrete with a 28-day strength of 4000 psi. The reinforcement used for the walls will be grade 60 #4 rebars in both horizontal and vertical directions. This reinforcement will add tensile reinforcement and will help prevent thermal cracking. The specifications for the concrete walls were found in chapter 6.7 of Iowa DOT Design Manual and chapter 19 of the International Building Code 2018. The stairs were designed to split the seating in half and have a total width of 4’. The stairs need to cover a total span of 22’ and a height of 4’ 6”. 12 total steps are needed in order to do so. Each step will have a tread depth of 1’ 9” and a riser height of 4.5”. The concrete used should have a compressive strength of 4000 psi and should use grade 60 #4 rebar for tensile reinforcement. The design specifications for the stairs for the stairs were found in section 9080.102 SUDAS Standards Specifications manual. Calculations on the concrete walls and stairs can be found in Appendix B on page 29-32. The drawings for the walls and stairs can be found in the plan view drawings on Sheet C.2 and Sheet C.3, respectively.

Seating and Accessible Seating Dimensions

As stated above, the seating was built up by concrete retaining wall arcs. The arcs add up to a total length of about 190’. Using a width of 20” per seat allows for at least 115 people. The desired number of seats for the design was between 100 and 150 people, therefore the design is adequate to hold the size of the desired audience. The height and width per seat were based off of typical dimensions of an American stadium seat. Calculations for the seating dimensions can be found in Appendix B. According to the Americans with Disabilities Act for stadium seating, 1%

of seating should be accessible seating. In order to achieve this, a concrete slab was included in front of the seating to accommodate two accessible seats. The slab has a 2% slope to prevent water from pooling on the slab. Calculations on the seating can be found in Appendix B on page 34.

Drainage

Although the flow of rainwater for the site is directed around the seating, there will still be rain that will fall on the grass between the seats. In order to prevent water from pooling in this area, drainage holes need to be included in the concrete walls. The holes are designed to be 3” in diameter and are spaced out every 4’ on each tier of seats. Below the grass, a gravel subbase with an impermeable surface below it is included to promote the water to flow through the drainage holes. The cross section with the drainage schematic can be seen in the plan view drawings. The drainage requirements were found in section 9071 of the Iowa DOT design manual.

Hydraulic Analysis

Pre and post-development hydraulic analyses were performed based on Chapter 2 of the SUDAS Design Manual. The rational method was used because the drainage area was smaller than 10 acres. The drainage area was measured using ArcGIS, which yielded an area of approximately four acres. The peak discharge for the pre-development hydraulic analysis was calculated to be 3.9 cubic feet per seconds. Post-development was calculated as 4.0 cubic feet per second. It was determined that the change in discharges was insignificant and no further hydraulic design was needed. Calculations on the hydraulic analysis can be found in Appendix C on page 35-37.

Parking Design

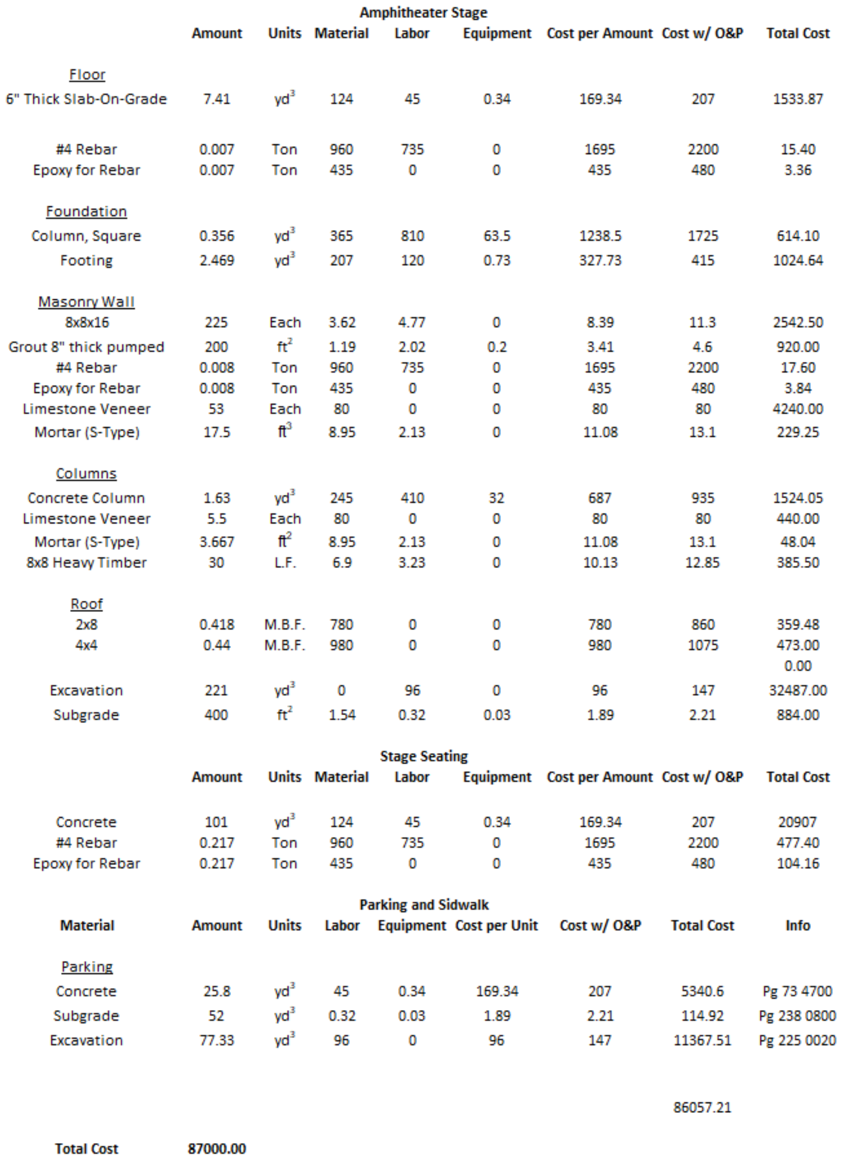
The location of the site was determined to be a commercial recreation zone. Per Article VI of the Boone County Zoning Ordinance, a commercial recreation zone requires one parking space per four persons of licensed capacity. The amphitheater is designed for a capacity of 100-150 persons, which would require at least 38 parking spaces. According to the Americans with Disabilities Act Standards for Accessible Design 4.1.2 (5), of the 38 parking spaces, at least two are required to be accessible parking spaces. Of the accessible spaces, at least one is required to be van accessible. A standard van accessible space, per the Iowa SUDAS Design Manual, is eighteen feet long and eleven feet wide with a five foot wide access aisle. With an eight foot wide access aisle, the standards allow that the van accessible space can be reduced to eight feet wide. This parking design uses two van accessible spaces that share an eight foot access aisle. The layout of the accessible parking can be found in Appendix D on page 39.

In addition to the parking spaces, a concrete pad was designed to aid drivers in entering and exiting each space. Using the swept path analysis tool from Autodesk, it was determined that the pad should extend eight feet beyond the edge of the parking spaces to provide enough space to turn into and out of the parking spaces without driving through mud or grass. The pad will replace the existing road near the parking spaces. Since the existing road is 24 feet wide, the dimensions of the pad will be 40 feet long and 24 feet wide. The swept path analysis can be found in Appendix D on page 38.

Section 8B-1 of the Iowa SUDAS Design Manual was used to determine the required thickness of the pavement. There was no soil test available to determine the CBR value, so a CBR value of 3 and a non-uniform subgrade were assumed. Based on Table 8B-1.03 from the SUDAS design manual, the thickness used for the design was six inches on top of twelve inches of prepared subgrade. Combining the thickness with the total area of the parking spaces and the concrete pad yielded a volume of 696 cubic feet of concrete and 1392 cubic feet of subgrade.

Section VII - Engineer’s Cost Estimate

The cost estimate was done using the 2017 RS Means catalog. RS Means uses the national average to determine costs of almost any construction item thought of. For this project the Heavy Construction Cost Data book was used. Since the 2017 book was used the cost of items was increased by a little under 1% from the 2017 average to predict inflation into the 2018 year. Overhead and Profit (O&P) was not marked up and there were no contingency costs added. The O&P strictly includes the material, labor, and the equipment used. Therefore, the total cost is a reflection of those three items.



Amphitheater Stage

	Amount	Units	Material	Labor	Equipment	Cost per Amount	Cost w/ O&P	Total Cost
Floor								
6" Thick Slab-On-Grade	7.41	yd^3	124	45	0.34	169.34	207	1533.87
#4 Rebar	0.007	Ton	960	735	0	1695	2200	15.40
Epoxy for Rebar	0.007	Ton	435	0	0	435	480	3.36
Foundation								
Column, Square	0.356	yd^3	365	810	63.5	1238.5	1725	614.10
Footing	2.469	yd^3	207	120	0.73	327.73	415	1024.64
Masonry Wall								
8x8x16	225	Each	3.62	4.77	0	8.39	11.3	2542.50
Grout 8" thick pumped	200	ft^2	1.19	2.02	0.2	3.41	4.6	920.00
#4 Rebar	0.008	Ton	960	735	0	1695	2200	17.60
Epoxy for Rebar	0.008	Ton	435	0	0	435	480	3.84
Limestone Veneer	53	Each	80	0	0	80	80	4240.00
Mortar (S-Type)	17.5	ft^3	8.95	2.13	0	11.08	13.1	229.25
Columns								
Concrete Column	1.63	yd^3	245	410	32	687	935	1524.05
Limestone Veneer	5.5	Each	80	0	0	80	80	440.00
Mortar (S-Type)	3.667	ft^2	8.95	2.13	0	11.08	13.1	48.04
8x8 Heavy Timber	30	L.F.	6.9	3.23	0	10.13	12.85	385.50
Roof								
2x8	0.418	M.B.F.	780	0	0	780	860	359.48
4x4	0.44	M.B.F.	980	0	0	980	1075	473.00
								0.00
Excavation	221	yd^3	0	96	0	96	147	32487.00
Subgrade	400	ft^2	1.54	0.32	0.03	1.89	2.21	884.00

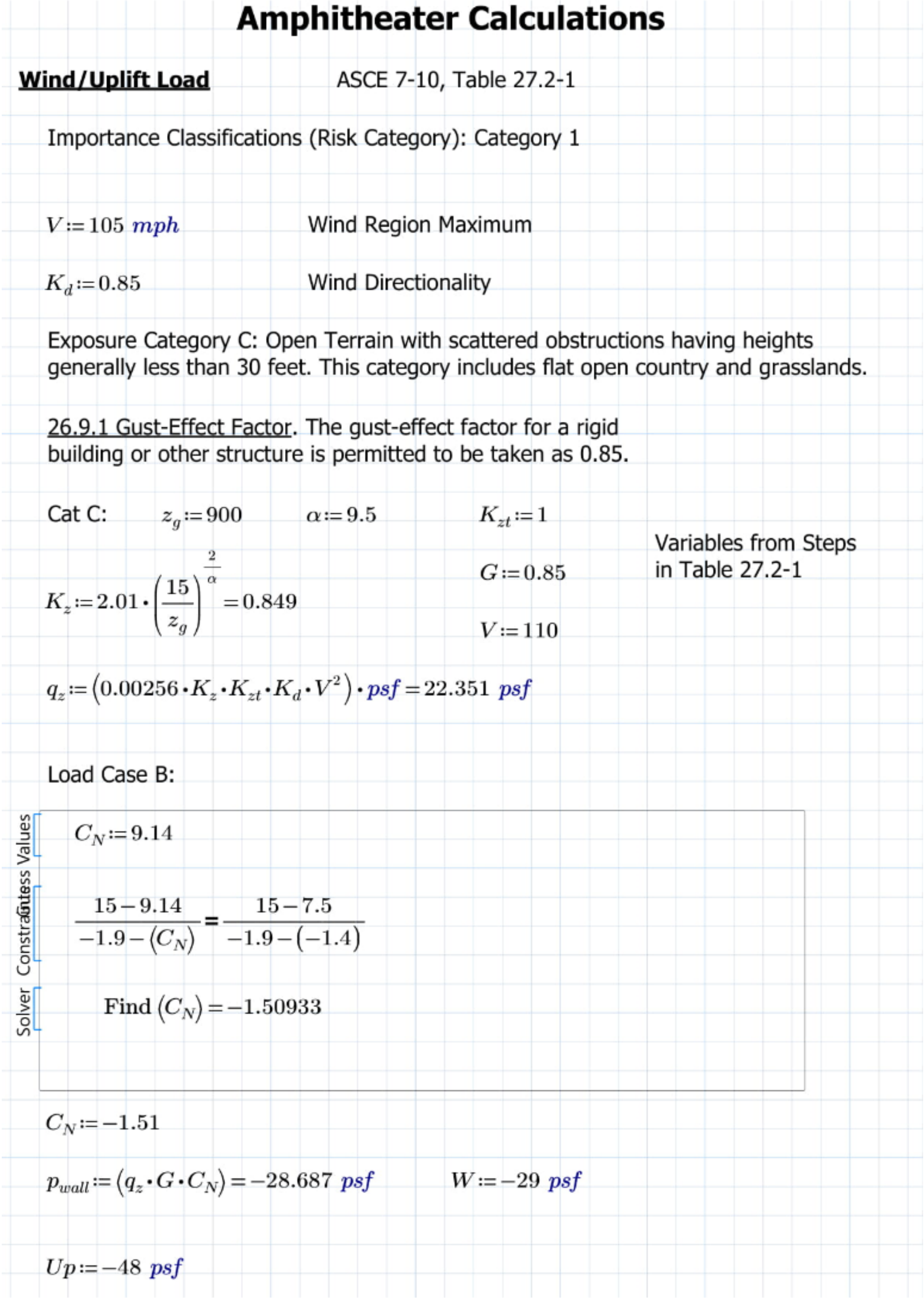
Stage Seating

	Amount	Units	Material	Labor	Equipment	Cost per Amount	Cost w/ O&P	Total Cost
Concrete	101	yd^3	124	45	0.34	169.34	207	20907
#4 Rebar	0.217	Ton	960	735	0	1695	2200	477.40
Epoxy for Rebar	0.217	Ton	435	0	0	435	480	104.16

Parking and Sidwalk

Material	Amount	Units	Labor	Equipment	Cost per Unit	Cost w/ O&P	Total Cost	Info
Parking								
Concrete	25.8	yd^3	45	0.34	169.34	207	5340.6	Pg 73 4700
Subgrade	52	yd^3	0.32	0.03	1.89	2.21	114.92	Pg 238 0800
Excavation	77.33	yd^3	96	0	96	147	11367.51	Pg 225 0020
							86057.21	
Total Cost	**87000.00**							

Appendix A: Design Calculations for Amphitheater Stage



Amphitheater Calculations

Wind/Uplift Load ASCE 7-10, Table 27.2-1

Importance Classifications (Risk Category): Category 1

$V := 105\ mph$ Wind Region Maximum

$K_d := 0.85$ Wind Directionality

Exposure Category C: Open Terrain with scattered obstructions having heights generally less than 30 feet. This category includes flat open country and grasslands.

26.9.1 Gust-Effect Factor. The gust-effect factor for a rigid building or other structure is permitted to be taken as 0.85.

Cat C: $z_g := 900$ $\alpha := 9.5$ $K_{zt} := 1$

Variables from Steps in Table 27.2-1

$G := 0.85$

$$K_z := 2.01 \cdot \left(\frac{15}{z_g}\right)^{\frac{2}{\alpha}} = 0.849$$

$V := 110$

$$q_z := \left(0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2\right) \cdot psf = 22.351\ psf$$

Load Case B:

$C_N := 9.14$

$$\frac{15-9.14}{-1.9-\left(C_N\right)} = \frac{15-7.5}{-1.9-(-1.4)}$$

$$\text{Find}\left(C_N\right) = -1.50933$$

$C_N := -1.51$

$p_{wall} := \left(q_z \cdot G \cdot C_N\right) = -28.687\ psf$ $W := -29\ psf$

$Up := -48\ psf$

Snow Load Calculation ASCE 7-16 Ch 7

pf is the flat roof snow load
Cs is the slope roof factor

$C_e := 0.9$ Exposure Factor

$C_t := 1.2$ Thermal Factor

$I_s := 1$ Importance Factor

$\rho_g := 30\ psf$ Ground Snow Load, Average IBC 2015

$\rho_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot \rho_g = 22.68\ psf$ Snow Load for Design

$C_{s30} := 1$ $C_{s45} := 1$ $C_{s60} := 0.3$ Various Angle Factors

$\rho_{s30} := C_{s30} \cdot \rho_f = 22.68\ psf$

Multiple Roof Angle Loads

$\rho_{s60} := C_{s60} \cdot \rho_f = 6.804\ psf$

Dead Load of Roof Calculation

4x4 Lumber

$n_{H\_4x4} := 22$

$A_{H4x4} := 3.75\ in \cdot 3.75\ in \cdot 1\ in = 14.063\ in^3$

$\rho_{roof4x4} := 35\ pcf$

$w_{4x4} := \rho_{roof4x4} \cdot A_{H4x4} = 0.285\ lbf$

Notes:
All Sawn Lumber,
NDS - Pg 14

2x8 Lumber

$n_{2x8} := 19$

$A_{2x8} := 1.5\ in \cdot 7.25\ in \cdot 1\ in = 10.875\ in^3$

$\rho_{roof2x8} := 35\ pcf$

$w_{2x8} := A_{2x8} \cdot \rho_{roof2x8} = 0.22\ lbf$

$TW_{roof} := w_{2x8} + w_{4x4} = 0.505\ lbf$

$D := \frac{TW_{roof}}{400\ ft^2} = 0.00126\ psf$

Design Roof Load

LRFD Structural Loads and Load Combinations:

$D_{LRoof} := 0.00126\ psf$

$Up := -48\ plf$

$L_L := 150\ psf$ IBC 2015 for Stages (Live Load applicable to Flooring Only)

$S := 22.68\ psf$

$L_R := 20\ psf$

$W := -29\ psf$

Load Combos:

$Load1 := 1.2 \cdot D_{LRoof} = 0.002\ psf$

$Load2 := 1.2 \cdot D_{LRoof} + L_L + 0.5 \cdot S = 161.342\ psf$

$Load2_{Vertical} := 1.2 \cdot D_{LRoof} + 0\ psf + 0.5 \cdot S = 11.342\ psf$

$Load3 := 1.2 \cdot D_{LRoof} + 1.6 \cdot S + 0.5 \cdot W = 21.79\ psf$

$Load4 := 1.2 \cdot D_{LRoof} + 1.0 \cdot W + 0\ psf + 0.5 \cdot S = -17.658\ psf$

$Load5 := 1.2 \cdot D_{LRoof} + 0.2 \cdot S = 4.538\ psf$

$Load6 := 0.9 \cdot D_{LRoof} + 1.0 \cdot W = -28.999\ psf$

Foundation Calculations for Wall Side:

Assumptions:

$GWT := 9.5\ ft$	Based on nearby data near Marshalltown given by USGS
$\gamma_{backfill} := 120\ pcf$	Gravel unit weight
$\phi' := 35\ deg$	Friction Angle
$B := 5\ ft$	Width of Foundation
$D_f := 3\ ft$	Depth of the Bottom of the Footing
$E_s := 3000\ psi$	Strength of the Soil

Variables:

$\gamma_m := 125\ pcf$	Unit weight of Masonry
$\gamma_{situ} := 94\ pcf$	Soil in given area is considered "Sandy Loam"
$\gamma_w := 62.4\ pcf$	Unit Weight of Water
$\mu_s := 0.25$	Coefficient of Friction of the Soil
$\gamma_c := 150\ pcf$	Unit weight of Concrete
$L := 20\ ft$	Length of proposed Foundation
$t_c := 6\ in$	Thickness of Concrete
$t_f := 8\ in$	Thickness of the Footing

Calculations:

$$w_{wall} := 20\ ft^2 \cdot \gamma_m \cdot 12\ in = 2.5\ kip$$

Weight of the Masonry Wall

$$P_{top} := Load3 \cdot 20\ ft^2 = 0.436\ kip$$

Point Load on Wall from Roof Loading

$$P_{foundation} := \frac{P_{top} + w_{wall}}{1\ ft} = 2.936\ \frac{kip}{ft}$$

Point Load on Foundation from Weight of Wall and Roof Loading

$$M := \frac{\begin{array}{c}-29\ plf \cdot 5\ ft \cdot 10\ ft \hookleftarrow \\ + \sin(9.14) \cdot (Up \cdot 5\ ft \cdot 10\ ft)\end{array}}{1\ ft} = -2.124\ \frac{kip \cdot ft}{ft}$$

Moment on Wall given by Uplift and Horizontal Pressure of the Wind

$$e := \left| \frac{M}{P_{foundation}} \right| = 8.683\ in$$

Eccetricity given by the Point Load and Moment

Foundation Design Calculations:

$$B_{min} := 6 \cdot e = 4.341\ ft$$

$$B' := B_{min} - 2 \cdot e = 2.894\ ft$$

$$q := \frac{P_{foundation} \cdot L}{B_{min} \cdot L} + \gamma_c \cdot t_c + \gamma_{backfill} \cdot (3\ ft - t_f) + (\gamma_m \cdot 1\ ft) = 1156.223\ psf$$

$$q_{allow} := 2000\ psf$$

$$q \le q_{allow} = 1$$

Design is OK for bearing pressure

IBC allows only 2000 psf for this type of soil

Vesics Factors

$$N_q := e^{\pi \cdot \tan(\phi')} \cdot \left(\tan\left(45\,° + \frac{\phi'}{2}\right)\right)^2 = 33.296$$

$$N_c := \frac{N_q - 1}{\tan(\phi')} = 46.124$$

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi') = 48.029$$

$$d_c := 1 + 0.4 \cdot \left(\frac{D_f}{B}\right) = 1.24$$

$$d_q := 1 + 2\ \tan(\phi') \cdot (1 - \sin(\phi'))^2 \cdot \left(\frac{D_f}{B}\right) = 1.153$$

$$d_\gamma := 1$$

$$s_c := 1 + \frac{N_q}{N_c} \cdot \frac{B'}{L} = 1.104$$

$i_c := 1$

No inclination factors required

$$s_q := 1 + \frac{B'}{L} \cdot \tan(\phi') = 1.101$$

$i_q := 1$

$$s_\gamma := 1 - 0.4 \cdot \frac{B'}{L} = 0.942$$

$i_\gamma := 1$

$$q_n := (\gamma_w \cdot D_f) \cdot N_q \cdot s_q \cdot d_q \cdot i_q + 0.5 \cdot \gamma_{situ} \cdot B' \cdot N_\gamma \cdot s_\gamma \cdot d_\gamma \cdot i_\gamma = 14068.724\ psf$$

$$FS := \frac{q_n}{q} = 12.168$$

$FS > 3 = 1$

Factor of Safety for Bearing Capacity is greater than 3 and is sufficient

$\frac{B}{L} \le 6 = 1$

No Uplift from the Soil

Wall Foundation Settlement Calculations:

$$q_{net} := \left(\frac{P_{foundation} \cdot L}{B_{min} \cdot L}\right) + \left(\gamma_c \cdot 0.5\ ft\right) + \left(\gamma_{backfill} \cdot \left(3\ ft - t_f\right)\right) - \left(\gamma_{situ} \cdot 3\ ft\right) = 749.223\ psf$$

$$\alpha := 4$$

$$H := 5 \cdot B_{min} = 21.707\ ft$$

$$B'_2 := 0.5 \cdot B_{min} = 2.171\ ft$$

$$M := \frac{L}{B_{min}} = 4.607 \qquad N := \frac{H}{B'_2} = 10$$

$$I_1 := 0.770$$

$$I_2 := 0.091$$

$$I_s := I_1 + \left(\frac{1 - 2 \cdot \mu_s}{1 - \mu_s}\right) \cdot I_2 = 0.831$$

$$\frac{D_f}{B_{min}} = 0.691 \qquad I_f := 0.8$$

$$\frac{B_{min}}{L} = 0.217$$

$$S_{e1} := q_{net} \cdot \left(\alpha \cdot B_{min}\right) \cdot \left(\frac{1 - {\mu_s}^2}{E_s}\right) \cdot I_s \cdot I_f = 0.225\ in$$

$$S_{e1} \le \frac{1}{2}\ in = 1$$

Settlement of the Footing is less than 1/2 in and is acceptable

Foundation Calculations for Columns:

Assumptions: All assumptions are the same as the previous foundation.

$B := 3\ ft$ Width of Footing

Note: Calculations below are for each individual column, they receive the same amount of force.

Variables:

$Up := -48\ psf$ Vertical Uplift Pressure

$Load3 := 1.2 \cdot D_{LRoof} + 1.6 \cdot S + 0.5 \cdot Up = 12.29\ psf$ Load 3 is changed due to Vertical Loading on the Roof

$L := 3\ ft$ Length of Individual Column Footings

Calculations:

$P_{top} := Load3 \cdot 100\ ft^2 = 1.229\ kip$ Loading on Roof for Tributary Area of one Column

$P_{foundation} := \frac{P_{top}}{1\ ft} = 1.229\ \frac{kip}{ft}$ Loading on Column Foundation

$P_{column} := 7.5\ in \cdot |W| = 18.125\ plf$ Horizontal Loading on face of Column

$M := \frac{29\ plf \cdot 7.5\ in \cdot 14\ ft}{1\ ft} = 0.254\ \frac{kip \cdot ft}{ft}$ Moment on Column given by Uplift and Horizontal Pressure of the Wind

$e := \left| \frac{M}{P_{foundation}} \right| = 2.478\ in$ Eccetricity given by the Point Load and Moment

$B_{min} := 6 \cdot e = 1.239\ ft$

$B' := B_{min} - 2 \cdot e = 0.826\ ft$

$$q := \frac{P_{foundation} \cdot L}{B_{min} \cdot L} + \gamma_c \cdot t_c + \gamma_{backfill} \cdot (3\ ft - t_f) + Up \cdot \sin(9.14) = 1333.515\ psf$$

$q_{allow} := 2000\ psf$

$q \le q_{allow} = 1$ Design is OK for bearing pressure

Vesics Factors

$$N_q := e^{\pi \cdot \tan(\phi')} \cdot \left(\tan\left(45\ ° + \frac{\phi'}{2}\right)\right)^2 = 33.296$$

$$N_c := \frac{N_q - 1}{\tan(\phi')} = 46.124$$

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi') = 48.029$$

$$d_c := 1 + 0.4 \cdot \left(\frac{D_f}{B}\right) = 1.4$$

$$d_q := 1 + 2\ \tan(\phi') \cdot (1 - \sin(\phi'))^2 \cdot \left(\frac{D_f}{B}\right) = 1.255$$

$$d_\gamma := 1$$

$$s_c := 1 + \frac{N_q}{N_c} \cdot \frac{B'}{L} = 1.199 \qquad i_c := 1$$

$$s_q := 1 + \frac{B'}{L} \cdot \tan(\phi') = 1.193 \qquad i_q := 1$$

$$s_\gamma := 1 - 0.4 \cdot \frac{B'}{L} = 0.89 \qquad i_\gamma := 1$$

$$q_n := (\gamma_{situ} \cdot D_f) \cdot N_q \cdot s_q \cdot d_q \cdot i_q + 0.5 \cdot \gamma_{situ} \cdot B' \cdot N_\gamma \cdot s_\gamma \cdot d_\gamma \cdot i_\gamma = 15710.482\ psf$$

$$FS_q := \frac{q_n}{q} = 11.781$$

Column Foundation Settlement Calculations:

$$q_{net} := \left(\frac{P_{foundation} \cdot L}{B_{min} \cdot L}\right) + \left(\gamma_c \cdot 0.5\ ft\right) + \left(\gamma_{backfill} \cdot \left(3\ ft - t_f\right)\right) - \left(\gamma_{situ} \cdot 3\ ft\right) = 1065.001\ psf$$

$\alpha := 4$

$H := 5 \cdot B_{min} = 6.194\ ft$

$B'_2 := 0.5 \cdot B_{min} = 0.619\ ft$

$M := \dfrac{L}{B_{min}} = 2.422$ $\qquad$ $N := \dfrac{H}{B'_2} = 10$

$I_1 := 0.770$

$I_2 := 0.091$

$$I_s := I_1 + \left(\frac{1 - 2 \cdot \mu_s}{1 - \mu_s}\right) \cdot I_2 = 0.831$$

$\dfrac{D_f}{B_{min}} = 2.422$

$I_f := 0.8$

$\dfrac{B_{min}}{L} = 0.413$

$$S_{e1} := q_{net} \cdot \left(\alpha \cdot B_{min}\right) \cdot \left(\frac{1 - {\mu_s}^2}{E_s}\right) \cdot I_s \cdot I_f = 0.091\ in$$

$S_{e1} \le \dfrac{1}{2}\ in = 1$

Settlement of the Footing is less than 1/2 in and is acceptable

Masonry Wall Calculations:

Design Block: 16"x8"x8", Fully Grouted

Reference: The Masonry Society, *Masonry Structures Behavior and Design*

Assumptions:

$f_m' := 2\ ksi$

$\phi := 0.6$

Variables:

$I := 443.3\ in^4$ $A_n := 91.5\ in^2$ $k := 10\ ft$

$Load3 := 1.2 \cdot D_{LRoof} + 1.6 \cdot S + 0.5 \cdot W = 21.79\ psf$

Calculations:

$r := \sqrt{\dfrac{I}{A_n}} = 2.201\ in$ Radius of Gyration

$\dfrac{k}{r} = 54.518$ $\dfrac{k}{r} \le 99 = 1$ Slenderness ratio ok

$P_u := Load3 \cdot 1\ ft \cdot 10\ ft = 217.895\ lbf$

$$\phi P_n := \phi \cdot 0.8 \cdot \left(0.8 \cdot A_n \cdot f_m' \cdot \left(1 - \left(\frac{k}{140 \cdot r}\right)^2\right)\right) = 59.616\ kip$$

$P_u < \phi P_n = 1$ Factored load is less than Nominal load, therefore design is satisfactory.

Net Compressive Stress Calculation:

$f_a := \dfrac{P_u}{A_n} = 342.917\ psf$

$f_{a\_Max} := \phi \cdot 0.8 \cdot f_m' = 138240\ psf$

$f_a \le f_{a\_Max} = 1$ Allowable compressive stress is lower than the maximum compressive stress, therefore design is satisfactory.

Concrete Floor Reinforcement/ Thermal Cracking

Assumption:

$C_o := 1\ in$

Variables:

$h := 6\ in$ Height of the Floor

$L := 20\ ft$

$W := 20\ ft$

$A_b := 0.2\ in^2$

#4 Rebar Dimensions

$d_b := 0.5\ in$

$F_y := 60\ ksi$ Yield Strength of the Rebar

Calculations:

$Co := C_o + 0.5 \cdot d_b = 1.25\ in$ Use this for concrete cover

$d_{eff} := h - Co = 4.75\ in$ Effective Depth of the Rebar

$\rho_{min} := 0.002$

$s_{st} := min(5 \cdot h, 18\ in) = 18\ in$ Minimum Spacing

$s := 2\ ft$ Two feet for spacing will be used

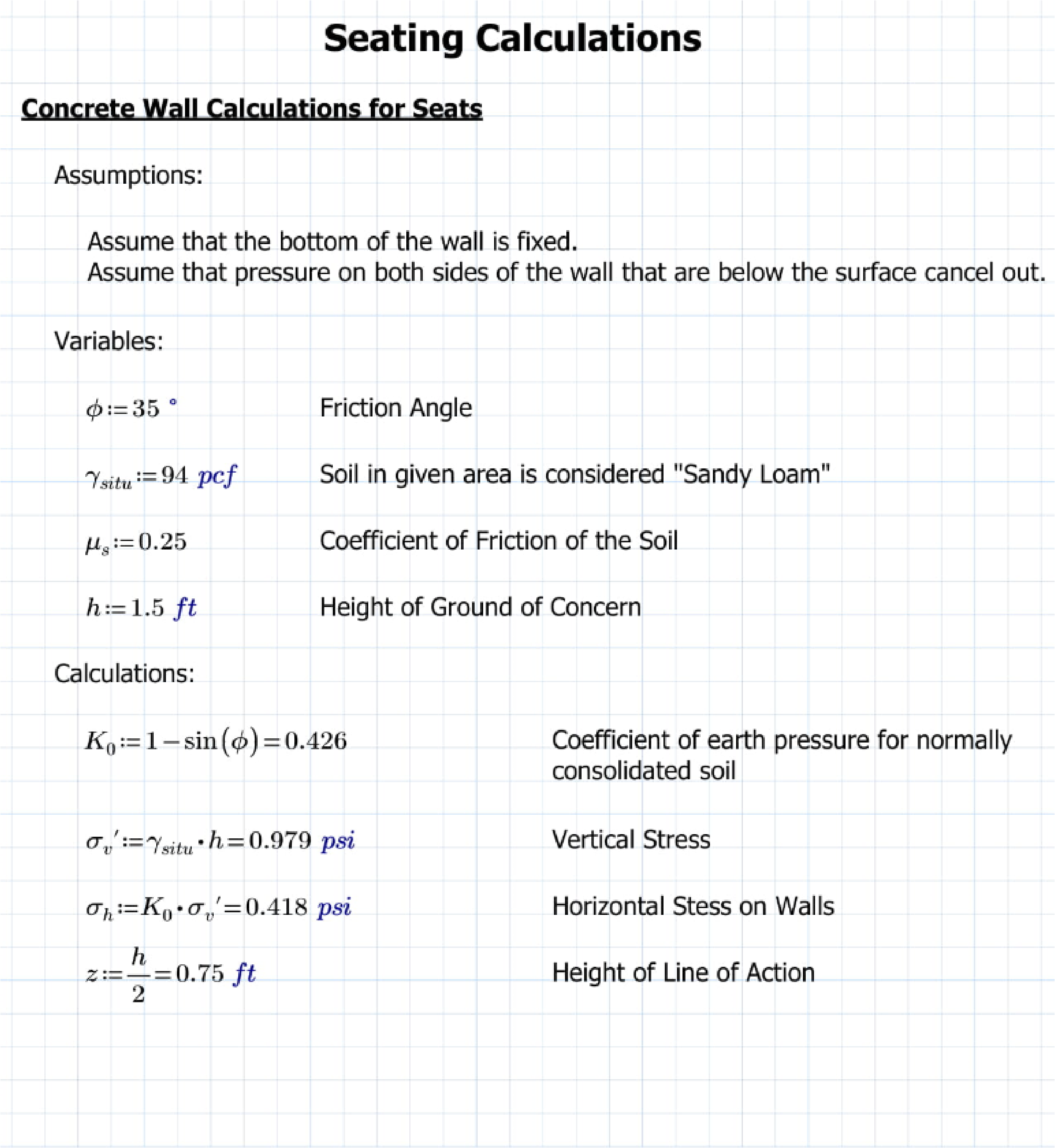
$EC_{min} := 2.5\ in$

Edge Clearance - IBC 2015, 3" will be used

$EC := 3\ in$

$n := 16$ Number of bars in both Horizontal and Vertical directions

Appendix B: Design Calculations for Seating



Seating Calculations

Concrete Wall Calculations for Seats

Assumptions:

Assume that the bottom of the wall is fixed.
Assume that pressure on both sides of the wall that are below the surface cancel out.

Variables:

$\phi := 35\ ^\circ$	Friction Angle
$\gamma_{situ} := 94\ pcf$	Soil in given area is considered "Sandy Loam"
$\mu_s := 0.25$	Coefficient of Friction of the Soil
$h := 1.5\ ft$	Height of Ground of Concern

Calculations:

$K_0 := 1 - \sin(\phi) = 0.426$	Coefficient of earth pressure for normally consolidated soil
$\sigma_v{}' := \gamma_{situ} \cdot h = 0.979\ psi$	Vertical Stress
$\sigma_h := K_0 \cdot \sigma_v{}' = 0.418\ psi$	Horizontal Stess on Walls
$z := \frac{h}{2} = 0.75\ ft$	Height of Line of Action

Rebar Needed for Seats

Assumption:

$C_o := 1\ in$

Variables:

$h_1 := 5\ ft \quad h_2 := h_1 \quad h_3 := h_1$

Arc Heights

$h_4 := 3.5\ ft$

$L_1 := 26.31\ ft$ Arc Lengths

$L_2 := 31.80\ ft$

$L_3 := 37.31\ ft$

$L_4 := 42.80\ ft$

$W := 1\ ft$

$A_b := 0.2\ in^2$

#4 Rebar Dimensions

$d_b := 0.5\ in$

$F_y := 60\ ksi$ Yield Strength of the Rebar

$w_b := 0.668\ \frac{lb}{ft}$

Calculations:

$Co := C_o + 0.5 \cdot d_b = 1.25\ in$

Use this for concrete cover

$d_{eff} := h - Co = 16.75\ in$

Effective Depth of the Rebar

$\rho_{min} := 0.002$

$s_{st} := min\left(5 \cdot h_1, 18\ in\right) = 18\ in$

Minimum Spacing

$s := 2\ ft$

Two feet for spacing will be used

$EC_{min} := 2.5\ in$

$EC := 3\ in$

Edge Clearance - IBC 2015,
3" will be used

$$n_{h1} := \frac{h_1 - 2 \cdot EC}{s} = 2.25$$

Number of bars in horizontal direction will be 3 for arcs 1 through 3

$n_{h1} := 3 \qquad n_{h2} := n_{h1} \qquad n_{h3} := n_{h1}$

$$n_{h4} := \frac{h_4 - 2 \cdot EC}{s} = 1.5$$

Number of bars in horizontal direction will be 2 for arc 4

$n_{h4} := 2$

$n_h := 6 \cdot n_{h1} + 2 \cdot n_{h4} = 22$

Total number of bars in horizontal direction

$$n_{v1} := \frac{L_1 - 2 \cdot EC}{s} = 12.905$$

Number of bars in vertical direction for arc 1

$n_{v1} := 13$

$$n_{v2} := \frac{L_2 - 2 \cdot EC}{s} = 15.65$$

Number of bars in vertical direction for arc 2

$n_{v2} := 16$

$$n_{v3} := \frac{L_3 - 2 \cdot EC}{s} = 18.405$$

Number of bars in vertical direction for arc 3

$n_{v3} := 19$

$$n_{v4} := \frac{L_4 - 2 \cdot EC}{s} = 21.15$$

Number of bars in vertical direction for arc 4

$n_{v4} := 22$

$n_v := 2 \cdot \left(n_{v1} + n_{v2} + n_{v3} + n_{v4}\right) = 140$

Total number of bars in vertical direction

$n := n_h + n_v = 162$

Total number of rebars

$$L_{rh1} := n_{h1} \cdot \left(L_1 - 2\ EC\right) = 77.43\ ft$$
$$L_{rh2} := n_{h2} \cdot \left(L_2 - 2\ EC\right) = 93.9\ ft$$
$$L_{rh3} := n_{h3} \cdot \left(L_3 - 2\ EC\right) = 110.43\ ft$$
$$L_{rh4} := n_{h4} \cdot \left(L_4 - 2\ EC\right) = 84.6\ ft$$

Total length of horizontal bars in each arc

$$w_{h1} := w_b \cdot L_{rh1} = 51.723\ lb$$
$$w_{h2} := w_b \cdot L_{rh2} = 62.725\ lb$$
$$w_{h3} := w_b \cdot L_{rh3} = 73.767\ lb$$
$$w_{h4} := w_b \cdot L_{rh4} = 56.513\ lb$$

Weights of bars in horizontal directions

$L_{rv1} := n_{v1} \cdot (h_1 - 2\ EC) = 58.5\ ft$ Total length of vertical bars in each arc

$L_{rv2} := n_{v2} \cdot (h_2 - 2\ EC) = 72\ ft$

$L_{rv3} := n_{v3} \cdot (h_3 - 2\ EC) = 85.5\ ft$

$L_{rv4} := n_{v4} \cdot (h_4 - 2\ EC) = 66\ ft$

$w_{v1} := w_b \cdot L_{rv1} = 39.078\ lb$ Weights of bars in vertical directions

$w_{v2} := w_b \cdot L_{rv2} = 48.096\ lb$

$w_{v3} := w_b \cdot L_{rv3} = 57.114\ lb$

$w_{v4} := w_b \cdot L_{rv4} = 44.088\ lb$

$w := w_{h1} + w_{h2} + w_{h3} + w_{h4} + w_{v1} + w_{v2} + w_{v3} + w_{v4} = 433.104\ lb$ Total weight

$L := L_{rh1} + L_{rh2} + L_{rh3} + L_{rh4} + L_{rv1} + L_{rv2} + L_{rv3} + L_{rv4} = 648.36\ ft$

$V_b := L \cdot A_b = 0.033\ yd^3$ Total volume of rebar

Drainage Holes in Concrete Walls

$433\ lb = 0.217\ ton$

Variables:

$s := 4\ ft$ Spacing of drainage holes

$d_h := 3\ in$ Diameter of drainage holes

$w := 1\ ft$ Width of concrete walls

Calculations:

$n := 2 \left(\frac{L_1}{s} + \frac{L_2}{s} + \frac{L_3}{s} \right) = 47.71$ Number of drainage holes

$n := 48$

$A_h := \frac{\pi}{4} \cdot {d_h}^2 = 7.069\ in^2$ Area of drainage holes

$V_h := n \cdot w \cdot A_h = 0.087\ yd^3$ Volume of drainage holes

Concrete Volume

Variables:

Volumes of each wall segment

$V_1 := 141.54\ ft^3$

$V_2 := 219.76\ ft^3$

$V_3 := 322.46\ ft^3$

$V_4 := 366.43\ ft^3$

$V_5 := 48\ ft^3$

$V_6 := 45.52\ ft^3$

$V_7 := 41.94\ ft^3$

$V_8 := 35\ ft^3$

$V_9 := 39\ ft^3$

$V_{10} := 48\ ft^3$

$V_{11} := 14\ ft^3$

$V_{12} := 32\ ft^3$

$V_{stairs} := 5.5\ ft^3 + 11 \cdot 3.5\ ft^3$

$V_{slab} := 15.98\ ft^3$

Calculations:

$$V_g := 2 \cdot \left(V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8 + V_9 + V_{10}\right) + V_{11} + V_{12} + V_{stairs} + V_{slab}$$

$V_g = 100.788\ yd^3$ Gross concrete volume

Gravel Sub-Base Volume

Variables:

$d := 1\ ft$ Depth of gravel sub-base

$$A_1 := \frac{180.35\ ft^2}{2}$$

$$A_2 := \frac{213.35\ ft^2}{2}$$

$$A_3 := \frac{246.28\ ft^2}{2}$$

Areas of gravel

Calculations:

$$V_{grav} := 2 \cdot d \cdot \left(A_1 + A_2 + A_3\right) = 23.703\ yd^3$$

Number of Seats

Variables:

$L_1 := 26.31\ ft$ $L_2 := 31.80\ ft$ $L_3 := 37.31\ ft$	Arc lengths on one side
$w := 20\ in$	Standard width for a seat

Calculations

$L := 2\ \left(L_1 + L_2 + L_3\right) = 190.84\ ft$	Total length of seats
$n := \dfrac{L}{w} = 115$	Number of seats

Step Dimensions

Variables:

$n_{sg} := 3$	Number of segments
$h_s := 1.5\ ft$	Height of seats
$L_s := 7\ ft$	Length of seat segments
$h_{max} := 7\ in$	Max seat height
$n_{ss} := 4$	Number of steps per segment

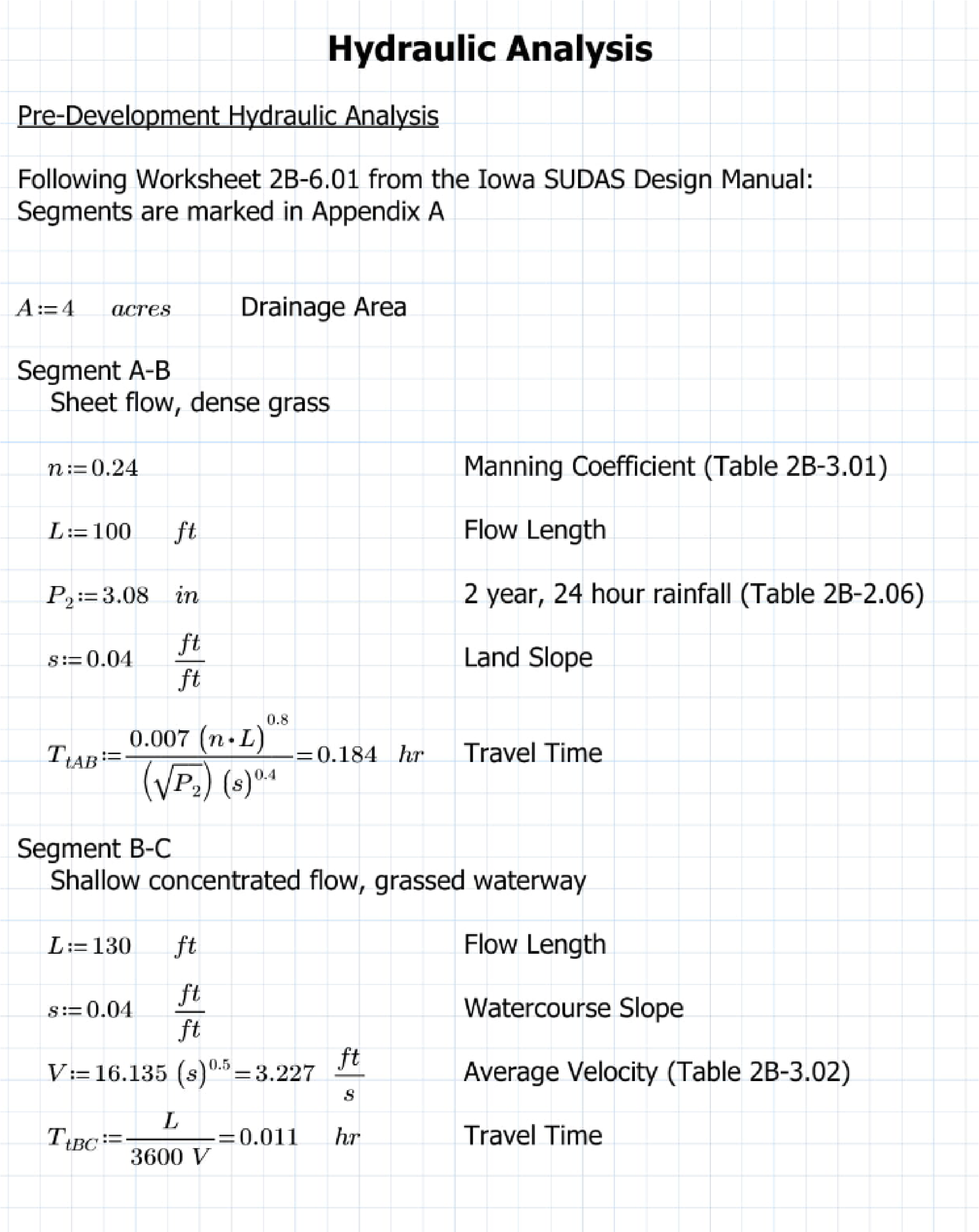
Calculations:

$h_{des} := \dfrac{h_s}{n_{ss}} = 4.5\ in$	Design step height
$L_{des} := \dfrac{L_s}{n_{ss}} = 21\ in$	Design step length
$n_s := n_{ss} \cdot n_{sg} = 12$	Number of steps

Handicapped Seating

$p_{min} := 1\% = 0.01$	Minimum percent of handicapped seating
$n_{handicapped} := n \cdot p_{min} = 1.15$	Number of handicapped seats required ∴ 2 handicapped seats are needed

Appendix C: Hydraulic Analysis Calculations



Hydraulic Analysis

Pre-Development Hydraulic Analysis

Following Worksheet 2B-6.01 from the Iowa SUDAS Design Manual:
Segments are marked in Appendix A

$A := 4 \quad acres$ Drainage Area

Segment A-B
Sheet flow, dense grass

$n := 0.24$ Manning Coefficient (Table 2B-3.01)

$L := 100 \quad ft$ Flow Length

$P_2 := 3.08 \quad in$ 2 year, 24 hour rainfall (Table 2B-2.06)

$s := 0.04 \quad \frac{ft}{ft}$ Land Slope

$T_{tAB} := \frac{0.007\,(n \cdot L)^{0.8}}{\left(\sqrt{P_2}\right)\,(s)^{0.4}} = 0.184 \quad hr$ Travel Time

Segment B-C
Shallow concentrated flow, grassed waterway

$L := 130 \quad ft$ Flow Length

$s := 0.04 \quad \frac{ft}{ft}$ Watercourse Slope

$V := 16.135\,(s)^{0.5} = 3.227 \quad \frac{ft}{s}$ Average Velocity (Table 2B-3.02)

$T_{tBC} := \frac{L}{3600\,V} = 0.011 \quad hr$ Travel Time

Segment C-D

Shallow concentrated flow, woodlands

$L := 240 \quad ft$ Flow Length

$s := 0.08 \quad \frac{ft}{ft}$ Watercourse Slope

$V := 5.032\ (s)^{0.5} = 1.423 \quad \frac{ft}{s}$ Average Velocity (Table 2B-3.02)

$T_{tCD} := \frac{L}{3600\ V} = 0.047 \quad hr$ Travel Time

Segment D-E

Shallow concentrated flow, grassed waterway

$L := 115 \quad ft$ Flow Length

$s := 0.08 \quad \frac{ft}{ft}$ Watercourse Slope

$V := 16.135\ (s)^{0.5} = 4.564 \quad \frac{ft}{s}$ Average Velocity (Table 2B-3.02)

$T_{tDE} := \frac{L}{3600\ V} = 0.007 \quad hr$ Travel Time

$T_c := T_{tAB} + T_{tBC} + T_{tCD} + T_{tDE} = 0.249 \quad hr$ Time of Concentration

$T_c := 0.249 \cdot 60 = 14.94 \quad min$

$C := 0.2$ Runoff Coefficient (Table 2B-4.01)

$i := 4.82 \quad \frac{in}{hr}$ Rainfall intensity for 10-year return, 15-min duration (Table 2B-2.06)

$Q := C \cdot i \cdot A = 3.86 \quad cfs$ Peak Runoff

Post-Development Hydraulic Analysis

Following Worksheet 2B-6.01 from the Iowa SUDAS Design Manual:
Segments are marked in Appendix A

$A := 4 \quad acres$ Drainage Area

Segments A-E
Same as Pre-Development

$T_{tAB} = 0.184 \quad hr \qquad T_{tBC} = 0.011 \quad hr \qquad T_{tCD} = 0.047 \quad hr \qquad T_{tDE} = 0.007 \quad hr$

Segment E-F
Shallow concentrated flow, pavement

$L := 40 \quad ft$ Flow Length

$s := 0.015 \quad \frac{ft}{ft}$ Watercourse Slope

$V := 20.238\,(s)^{0.5} = 2.479 \quad \frac{ft}{s}$ Average Velocity (Table 2B-3.02)

$T_{tEF} := \frac{L}{3600\ V} = 0.004 \quad hr$ Travel Time

$T_c := T_{tAB} + T_{tBC} + T_{tCD} + T_{tDE} + T_{tEF} = 0.253 \quad hr \qquad Tc := 0.253 \cdot 60 = 15.18 \ min$

Areas (square feet) $A_{stage} := 400 \qquad A_{prk} := 1392 \qquad A_{lawn} := 172616$

Rational Coefficients $C_{stage} := 0.95 \qquad C_{prk} := 0.95 \qquad C_{lawn} := 0.20$

Composite Runoff Coefficient:

$$C := \frac{\left(A_{stage} \cdot C_{stage} + A_{prk} \cdot C_{prk} + A_{lawn} \cdot C_{lawn}\right)}{A_{stage} + A_{prk} + A_{lawn}} = 0.21$$

$i := 4.82 \quad \frac{in}{hr}$

$Q := C \cdot i \cdot A = 4 \quad cfs$ Peak Runoff

Appendix D: Parking Design

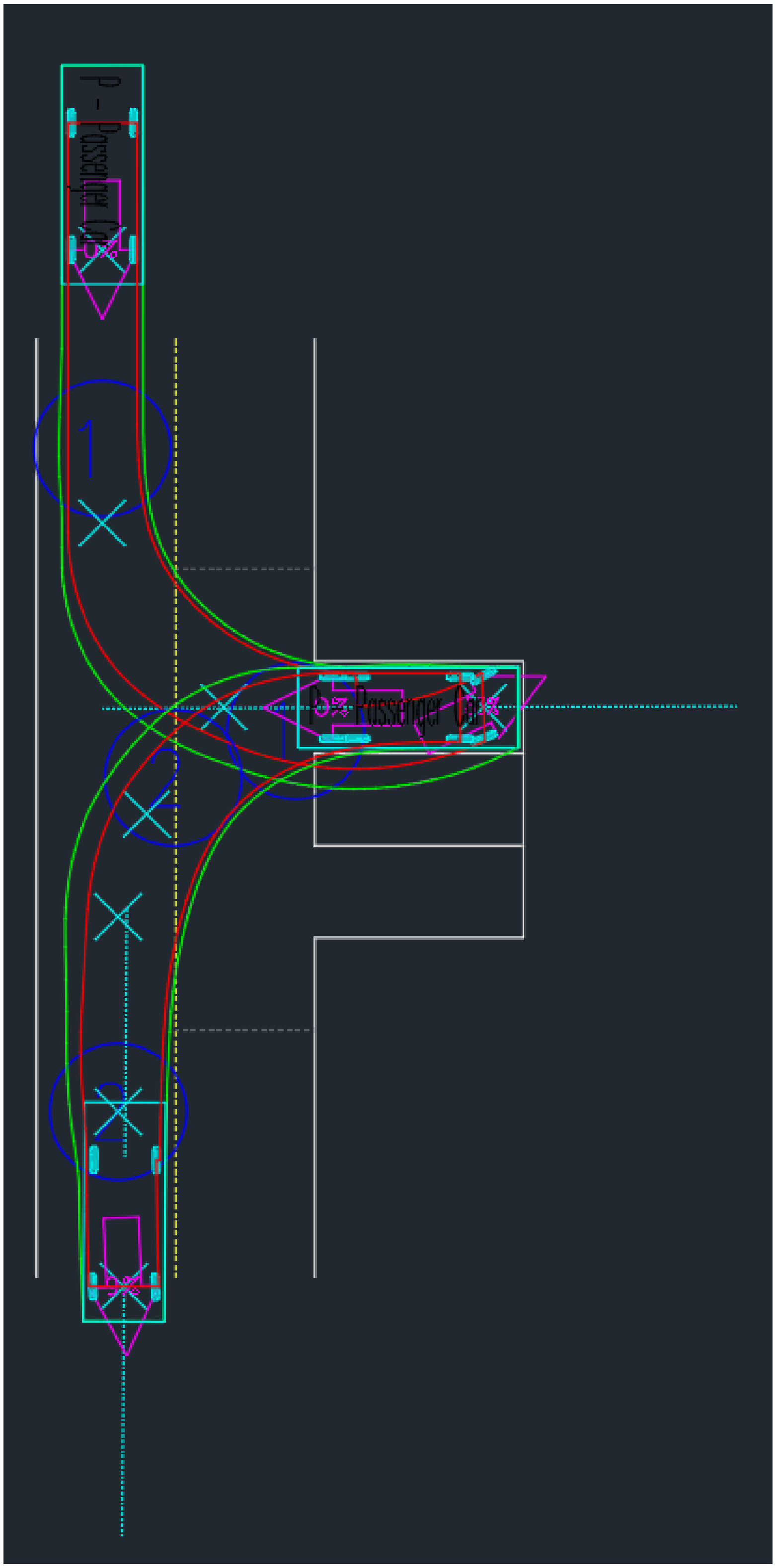


Figure 1: Swept Path Analysis

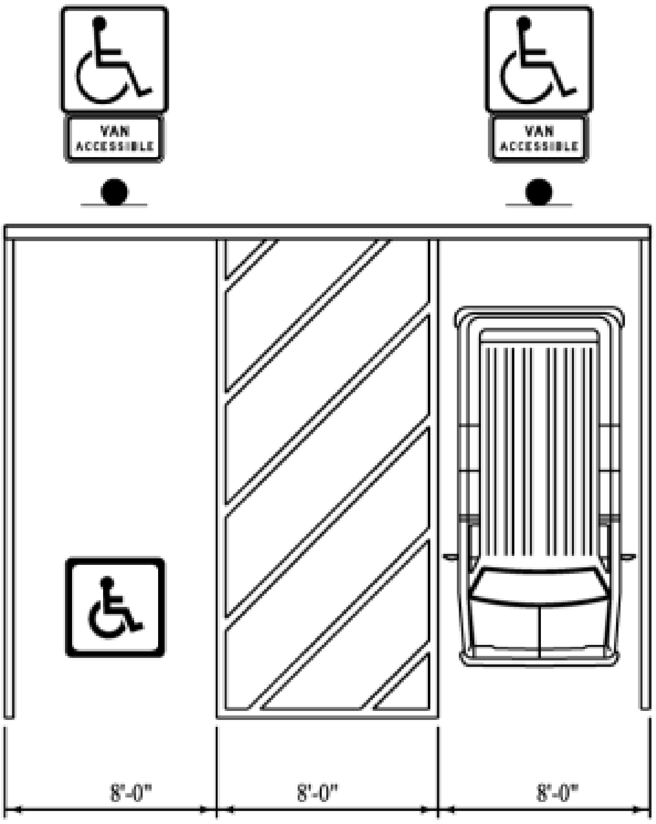


Figure 2: Van Accessible Parking Dimensions

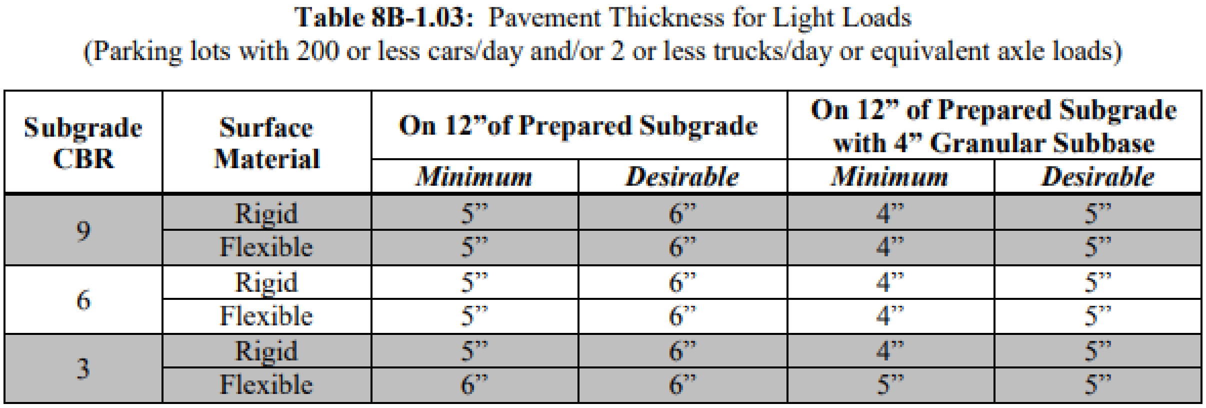


Table 8B-1.03: Pavement Thickness for Light Loads
(Parking lots with 200 or less cars/day and/or 2 or less trucks/day or equivalent axle loads)

Subgrade CBR	Surface Material	On 12"of Prepared Subgrade		On 12" of Prepared Subgrade with 4" Granular Subbase	
		Minimum	*Desirable*	*Minimum*	*Desirable*
9	Rigid	5"	6"	4"	5"
	Flexible	5"	6"	4"	5"
6	Rigid	5"	6"	4"	5"
	Flexible	5"	6"	4"	5"
3	Rigid	5"	6"	4"	5"
	Flexible	6"	6"	5"	5"

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